THE USE OF CONCRETE IN WATER WORKS CONSTRUCTION

Edgar B. Kay

Concrete plain or reinforced is so extensively employed not only in water works but in modern structures of all kinds, that a discussion of its use in the constructions of particular interest to this Association, seems almost unnecessary. Notwithstanding the very general and extensive employment of this material in hydraulic structures, frequent failures or partial failures have resulted from an imperfect knowledge of the physical and chemical properties of various kinds of cements, the proportioning of cements and aggregates, the determination of the amount and proper placing of steel reinforcement in reinforced concrete, the proper mixing and placing of the concrete, inexperience and carelessness in carrying out the construction, improper or premature loading, etc., in addition to the failures directly due to faulty design and faulty construction.

Dr. F. von Emperger in a paper presented at the Sixth Congress of the International Association for Testing Materials says:

> One of the chief causes of such accidents [accidents in building with reinforced concrete] has always resided in imperfect knowledge of the material at the time of removing the false work of the concrete, since in view of the divergent influences to which the material is exposed in building operations, the quality of the material can only be imperfectly judged in the laboratory; or also because, in the absence of any connection between the laboratory and the building site, the material has actually escaped any checking. It has happened, for instance, that the false work has been taken down from concrete which has been spoiled by frost or checked in its development, although the regulations laid down for ordinary average conditions have been strictly complied with; and that this premature dismantling of the false work has led to extensive accidents. Moreover, it has also happened that some contractors have had accidents when working on proved lines, through using materials to which they were not accustomed, without ascertaining whether the same were equal to those with which they were acquainted.

The failure of groined arches at Baltimore's new water filtration plant on October 20, 1913, is reported to have been due to the pre-

mature loading of concrete arches with earth fill without provision for taking up thrusts, the groins acting as cantilevers.

In the official report of Prof. M. Gary, on accelerated test for constancy of volume in Portland cements[1] he says:

> The desire for the discovery of a method of testing which will reveal dangerous changes in the volume of Portland cement with rapidity and reliability is nearly as old as Portland cement itself, and is thoroughly justified.
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> The evils that can be caused by expanding cement are greater than any that are attributable to any other defect exhibited by hydraulic binding media. Reference may be made to the extensive destruction in the buildings of the Cassel Courts of Justice some years ago, and also to the filtering plant at the new Wannsee water works, near Berlin, in 1911. True, in both cases it was a matter of using material of wrong composition, the injurious effects of which would certainly have been foreseen, even without the aid of any specially sensitive accelerated test, if an examination by the known standard method had been undertaken in good time. Instances may, however, be imagined in which the time available is insufficient for the performance of the cold water block test, which is the only one hitherto considered to be completely reliable, but necessitates the cement block to be kept under observation for several weeks.

With the tremendous growth of the industry and its wide application into new fields, there is no recognized standard test or specification now in use for concrete. There has not as yet been developed a set of standard tests or specifications the use of which will in all cases guarantee entirely satisfactory finished work.

The prescribed standard laboratory tests for the cement and the aggregate may be carefully and accurately carried out, and may show the materials to be good for the purpose, nevertheless if the workmanship is not equal to the materials employed, the result will be disappointing.

In 1903 and 1904 special committees were appointed by the American Society of Civil Engineers, American Society for Testing Materials, American Railway Engineering and Maintenance of Way Association and the Association of American Portland Cement Manufacturers for the purpose of investigating current practice and providing definite information concerning the properties of concrete and reinforced concrete and to recommend necessary factors and formulas required in the design of structures in which these materials are used. This joint committee at meetings at St. Louis in October,

[1] Proceedings Sixth Congress International Association for Testing Materials.

1904, and at New York in the following January perfected its organization and at the St. Louis meeting it was determined to arrange for tests at various technological institutions, some ten or more of which undertook a preliminary series of tests. The results thus obtained were collated and edited by the Secretary of the Committee at the Structural Materials Testing Laboratories of the U. S. Geological Survey at St. Louis. In June, 1905, the U. S. Geological Survey proposed to coöperate with the Joint Committee to the extent of placing the tests made at St. Louis Laboratory at the service of the committee with the privilege of adivsing as to the tests to be made. These tests covered a period of some five years and included a large number of tests of plain and reinforced concrete.

On June 30, 1910, Congress transferred the work of the Survey to the Bureau of Standards together with the data collected. It is understood that arrangements have been made by which the data of the tests will be published as rapidly as conditions permit.

In 1908 the committee began the preparation of the progress report which was submitted to the various organizations represented on the committee.

In the spring of 1911 the work of revising the 1909 progress report was again undertaken. Differences between the members of the committee were discussed and the revised report was finally adopted at a meeting held in New York November 20, 1912. The report was presented and accepted at the annual meeting of the American Society of Civil Engineers on January 15, 1913, and was also presented and adopted at the annual meeting of the American Railway Engineering Association on March 20, 1913, also adopted June 26, 1913, by the American Society for Testing Materials.

CONCRETE IN ANCIENT AND MODERN CONSTRUCTIONS

The increase from 82,000 barrels of Portland cement manufactured in the United States in 1880 to 80,000,000 barrels manufactured in 1911, due to the wide use of concrete in construction, has given popular expression to it as a new industry. Yet hydraulic cement has been employed in the oldest structures of which we have definite knowledge. The Egyptians 4000 years ago made a natural cement which set under water. While Carthage was at the height of her glory, over 2300 years ago, an aqueduct over 70 miles in length was built to furnish a water supply for that city. Natural cement

was used in its construction. To cross a valley over 1000 arches were built, many of them over 100 feet high, some of which are still standing. Cummings in his *American Cements* describing the Carthage aqueducts says that "at one point a piece of masonry over 100 feet long has fallen from the top of the aqueduct to the rocks below and still lies intact, unbroken, illustrating the toughness, tenacity and durability of the natural rock cement used by those early constructors."

E. B. Van Deman in the *American Journal of Archaeology* reviews the practice of construction of Roman buildings, in which he gives the essential features of Roman concrete construction, as found by a personal examination of most or all the concrete buildings belonging in the ten centuries from about 750 B.C. to about 300 A.D. From these examinations he concludes that until the second century B.C. concrete apparently was not in use. Somewhat before 100 B.C. some monumental structures containing concrete were erected. From that time on concrete construction increased in extent of use with considerable variation in its make up and in the nature of the facing. "In no period was concrete used to any extent without facing except in foundations and other invisible parts of buildings. Roughly at the beginning of the Christian era it reached the position of dominant material (or mode) of construction."

Throughout the entire Roman period, concrete was made of lime and pozzuolana (with admixture in some periods of a little neutral sand or gravel), and as aggregate, a considerable range of material, stone, brick and broken tile. During Julius Caesar's reign concrete became quite common for foundations and massive parts of masonry buildings, and some structures of this period are found which are wholly of concrete, with, however, the stone at the face laid or set, rather than deposited irregularly. Under Augustus concrete construction became practically universal, being used for foundations and massive parts of structures, for cores of walls, etc. Broken tile and brick are first found as a concrete aggregate in the period of Augustus and after Nero they are found abundantly. The concrete mortar used in the first and second centuries B.C. was composed of gray to gray-brown pozzuolanic sand with a poorly burned lime rather deficient in quality producing a friable mortar of gray color. Under Julius Caesar, a reddish pozzuolana was brought into use; a better variety of this became the standard mortar material in the

time of Augustus, a clean red pozzuolana which gives a quite characteristic color to the concrete of that period.

Besides the use of concrete in buildings, the Romans used this material for the construction of sewers, water mains, arches, aqueducts and highways.

The dome of the Pantheon, erected, A.D. 123, is perhaps the finest example of concrete construction coming down from the ancients. This structure, which is 142 feet in diameter and contains a 30-foot opening at the top, has withstood the destructive elements for nineteen centuries and is said to show not a crack today.

In the earliest concrete structures the pieces of stone (tufa) employed were very large, the maximum dimension often exceeding a foot. Aggregate that may be described as large continued in use for several centuries, and until broken tiles in large pieces began to appear.

From the downfall of the Roman Empire to the last half of the eighteenth century the manufacture of cement seems to have been discontinued.

In 1756 Smeaton discovered that an argillaceous limestone produced a lime that would set and harden under water, but no immediate appreciation of this knowledge appears to have resulted.

Natural cement was first produced in America in 1818 and reached a maximum production of nearly 10,000,000 barrels in 1899 and has since gradually decreased to about 900,000 barrels in 1911.

The distinguishing features between rubble masonry and concrete are really confined to the methods of mixing and placing the materials. The old Roman concrete was made with large stones and might be classed either as rubble or concrete masonry. The value of either rubble or concrete as a material for construction depends largely upon the quality of the cement used and the care exercised in the mixing and placing.

Examples of masonry structures composed of large stones reinforced or tied together with iron rods and bars are found in the works of all periods, but usually only in connection with cutstone masonry. With the advent of modern concrete the appropriateness of using reinforcing rods or bars of metal was soon discovered and taken advantage of. The compressive resistance of concrete is approximately ten times its tensile resistance. Volume for volume steel costs about fifty times as much as concrete. For the same sectional

areas steel will support in compression thirty times more load than concrete, and in tension three hundred times the load that concrete will carry. For the resistance of compressive loads, concrete will carry a given load at three-fifths or less of the cost required to support it with steel. On the other hand, to support a given load by concrete in tension would cost from five to six times as much as to support it with steel. If the various members of a structure could be so designed that all the compressive stresses are resisted by concrete and steel could be introduced to resist the tensile stresses, each material serving the purpose for which it is cheapest and best adapted, the ideal of economic design would be fulfilled.

CEMENTS

Cements are usually classified as follows: (1) Portland, (2) natural (3) pozzuolana, (4) blended or mixed. At least a score of varieties of hydraulic cement are listed in the classifications of cement technologists, but the American constructing engineer and contractor recognizes only the classes mentioned above. All concrete used in engineering work is made of either Portland, natural or slag cement, and only these three varieties are considered, here. The great bulk of all concrete work is made of Portland cement.

Portland cement is the best of the hydraulic cements. Being made from a rigidly controlled artificial mixture of lime, silica and alumina the product of the best mills is a remarkably strong, uniform and stable material. It is suitable for all classes of concrete work and is the only variety of hydraulic cement allowable for reinforced concrete or for plain concrete designed to endure hard wear or to be used where strength, density and durability of high degree are demanded. Portland cement is the finely ground powder of a clinker resulting from the incipient fusion of the above mentioned calcareous and argillaceous materials and must contain no materials added after calcination other than a small amount of calcium sulphate to regulate setting. The finished product contains at least 1.7 times as much lime, by weight, as silica, alumina and iron oxide combined. Mr. J. Y. Jewett, cement expert for U. S. Reclamation Service, in a paper read before the Sixth Congress of the International Association for Testing Materials, says:

> It is noted, that experience with the several brands used by the Service, both in the form of laboratory tests and of field use, shows that a good cement

can be made by the use of any of the methods and materials enumerated, provided proper care is taken in carrying out the details of the manufacturing process. It may be of interest to note that while these brands, as would be expected, show a diversity of results on the routine acceptance tests, even when meeting the specification requirements, practically all show a tendency to draw together and reach approximately the same values at long time periods.

Natural cement is the finely ground powder of a clinker, resulting from the burning, at a heat below incipient fusion, of argillaceous limestone or other suitable natural rock.

Natural cement may be substituted for Portland in concrete, if economy demands it, for dry unexposed foundations where the load in compression can never exceed, say 75 pounds per square inch (5 tons per square foot) and will not be imposed until three months after placing; for backing or filling in massive concrete or stone masonry where weight and mass are the essential elements; for subpavements of streets, and for sewer foundations.

In mortar natural cement is adapted for ordinary brickwork not subjected to high water pressure or to contact with water until, say, one month after laying, and for ordinary stone masonry where the chief requisite is weight and mass.

Natural cement concrete or mortar should never be allowed to freeze, should never be laid in water, in exposed situations, in columns, beams, floors or building walls, or in marine construction.

Pozzuolana or slag cement is made by intimately mixing granulated blast furnace slag of proper composition with slaked lime, and reducing this mixture to a fine powder. This product differs materially from Portland cement, although it is sometimes called a Portland cement by the manufacturers. While it is an excellent material for many purposes, it possesses certain qualities which prevent its use as a substitute for Portland cement in many classes of work. It will not stand exposure to the air and is very slow setting in tight forms.

Mixtures of Portland and natural cements, unless mixed at the factory and sold as a brand of natural hydraulic cement are not advised under any circumstances. The experience of the writer has shown that it is often difficult to control the use of two kinds of cement on a job, where, otherwise, it might be economic to use Portland cement for part of the work and a natural or pozzuolana cement on other parts. Even where there is no disposition on the part of the contractor to substitute the cheaper kind of cement, there

is the possibility of a mistake being made by careless workmen, and it is better to never allow or to specify the use of different kinds of cement on the same structure.

SAND OR FINE AGGREGATE

The term aggregate includes the stone and sand in concrete and may be classified as fine and coarse. The fine aggregate may be sand or crushed stone or gravel screenings, passing when dry a screen having $\frac{1}{4}$-inch diameter holes. Specifications usually require that sand for concrete shall be clean, sharp, and silicious in character. Neither sharpness nor excessive cleanliness is worth seeking after if it involves much expense. Tests have shown conclusively that sand with rounded grains makes quite as strong a mortar, other things being equal, as does sand with angular grains. The hardness of the separate particles is an important determination, increasing with the age of the concrete. As the cement hardens the aggregates tend to shear through and in the ideal monolith the grains should offer as high a resistance to crushing as the cement, after it has attained its greatest strength. Comparative sand tests of cement sand mortar should be based on compressive strength values instead of tensile strength values, since they conform in most cases to the conditions of actual construction. Concrete is never designed to withstand tensile stresses, without metal reinforcement. Experience has shown that the strengths obtained from a natural sand when made into a mortar of normal consistency are often equal to or greater than those obtained with the same cement, using Ottawa sand. When the same natural sand and cement are made into mortar of work consistency, the reduction of strength will be more or less marked, depending on the character of the natural sand. The strength of all sand mortars is affected by the amount of water used over that required for normal consistency. The more water used the greater will be the loss in strength at early periods. A fine sand takes much more water to produce a certain consistency of mortar when mixed with cement than does a coarse sand. A fine sand makes a weaker mortar than a coarse because of the lower density. It follows that if a mortar is less dense it must have more voids, and in the first mixing of the mortar these voids are filled with water. Hence when a mortar does require an excess of water, it is evident that the mortar produced will be less dense, and consequently will have lower strength. J. P. Brooks in *Reinforced Concrete* says:

By means of three tests that are readily made the relative value of various sands may be judged quite accurately. They are: (a) the appearance; (b) the feeling; (c) the weight. The better sands show a generous sprinkling of coarse grains mixed with the fine material and intermediate gradations. The grains should be of irregular shapes even though smooth; but sharpness is desirable. Upon rubbing the sand in the palm of the hand, traces of clay should be seen. The heavier the sand the better. Well shaken sand should weigh over 100 pounds per cubic foot when dry.

The only substitute for natural sand for concrete, that need be considered, is pulverized stone, either dust and fine screening produced in crushing rock or an artificial sand made by reducing suitable rocks to powder. The danger in using stone dust is failure to secure the proper balance of different size grains. The coarseness as well as the fineness of a good concrete sand is limited. The best sands will show not more than 40 per cent retained on the No. 10 sieve and not more than 5 per cent passing the No. 80 sieve.

PROPORTIONING CONCRETE

American engineers and contractors proportion concrete mixtures by measure, thus a 1–3–5 concrete is composed of 1 volume of cement, 3 volumes of sand and 5 volumes of aggregate. The volumetric method of proportioning is much more convenient in the field than to weigh the ingredients of each batch. In Continental Europe the gravimetric method of proportioning is very generally employed.

Depending upon the required density of the concrete, the task of proportioning consists in so proportioning the several materials that all void spaces are filled with finer material,—the voids between the larger aggregates being filled with the sand or fine aggregate, the voids between the sand filled with cement, and all aggregates large and small thoroughly coated with the cement paste.

Upon large or important structures it pays from an economic standpoint to make very careful studies of the materials of the aggregates and their relative proportions. Cement is always the most expensive ingredient, and any reduction of its quantity, which may very frequently be made by adjusting the proportions of the aggregate so as to use less cement and yet produce a concrete with the same density, strength and inpermeability, is of the utmost importance. Mr. W. B. Fuller has shown that by changing the ordinary mixture for watertight concrete, which is about 1: $2\frac{1}{2}$: $4\frac{1}{2}$, which requires 1.37 barrels of cement per cubic yard of concrete, by carefully grading

the materials by methods of mechanical analysis, he was able to obtain watertight work with a mixture of about 1: 3: 7, thus using 1.01 barrels of cement per cubic yard of concrete. This saving of 0.36 barrel is equivalent, with Portland cement at $1.60 per barrel to $0.58 per cubic yard of concrete.

The principles underlying the correct proportions of the materials are the same as those for mortar, namely, that the mass compacted shall have the greatest possible density. The theory of a concrete mixture has been well stated by Mr. Feret, as follows:

> The problem of making the best concrete is thus reduced to the selection of a mixture of materials whose granulometric composition corresponds to the maximum density, since when this composition is known, absolute volumes of cement may be substituted for equal absolute volumes of fine sand and vice-versa, so as to vary the strength, as desired while the density remains the same.

This is not strictly true for concrete mixtures because, when water is added to dry cement, the cement particles are separated from each other by the surface tension of the film of water, and it is not possible to obtain as dense a mixture as will be given by the dry mixture.

The density of concrete depends upon the varying degree of roughness of the stone and sand, the relative sizes of the diameters of the stone, sand and cement, and the amount of water used.

When loose sand is mixed with water, its volume or bulk is increased. Subsequent jarring will decrease its volume, but still leave a net gain of about 10 per cent. Not only does this increase in the volume of the sand occur, but, instead of increasing the voids that can be filled with cement, there is an absolute loss in the volume of available voids, due to the space occupied by the water necessary to bring the sand to the consistency of mortar.

When loose, dry Portland cement is wetted, it shrinks about 15 per cent in volume behaving differently from the sand, but it never shrinks back to quite as small a volume as it occupied when packed tightly in a barrel. The amount of cement paste that different brands of Portland cement will produce varies from 3.2 cubic feet based on a barrel of 3.8 cubic feet and for cement weighing 100 pounds per cubic foot there will be produced 0.86 cubic foot of paste.

Extensive tables of quantities of materials required in proportioning concrete for various mixtures are to be found in such treatises as *Concrete, Plain and Reinforced,* by Taylor and Thompson; *Concrete and Reinforced Concrete* by Reid; *Concrete Construction Methods and Cost* by Gillete and Hill.

MIXING AND PLACING CONCRETE

Mixing may be done either by hand or machine and the method to be employed is determined principally by the size of the job. A better and more uniform concrete can be made with a good machine mixer than by hand. A plastic concrete of a jelly-like consistency always produces stronger concrete than a wet mix and is preferred where conditions will admit of its use. It is absolutely necessary however, in reinforced concrete to employ a consistency sufficiently wet to flow around the steel and into the corners of the forms and in rubble concrete, to flow around the large stones. The batch type mixing machine should be used.

In handling and placing concrete, the materials must remain perfectly mixed, the aggregate must not separate from the mortar and the concrete must be rammed or agitated so as to thoroughly fill the forms and surround all parts of the steel reinforcement. Care must be taken to remove all sticks, blocks, shavings or similar materials from the forms before the concrete is placed and in case new concrete is deposited on a layer that has already set, the old surface should be roughened, cleaned and drenched with water before the new material is added. Concrete should be wet frequently for a few days after it is laid. The bonding of old and new concrete in walls or locations liable to tensile stress should be made by the use of a mortar richer in cement than the mortar in the concrete, a proportion of 1 to 2 is commonly employed.

The adhesive strength of cement or concrete is much less than its cohesive strength, so that in building thin walls for a tank or other work which must be watertight, the only sure method is to lay the structure as a monolith, without joints.

The placing of concrete under water requires the greatest care to prevent the cement from being washed out. Under no circumstances should concrete be placed in running water. Exposed concrete walls should not be plastered. It is a needless expense, and results in variable climates are unsatisfactory. It is difficult to apply cement mortar uniformly on the face of hardened concrete, and it is apt to crack off and discolor, especially if the concrete behind it is porous enough for water to penetrate it.

WATER-TIGHTNESS

A wall of concrete may be rendered water-tight in various ways:

1. By accurately grading and proportioning the aggregates and the cement. The proportions employed to resist the percolation of water usually range from 1: 1: 2 to 1: 2½: 4½ the most common mixture being 1: 2: 4 or 1: 2½: 4½. With accurate grading by scientific methods, water-tight work may be obtained. For maximum water-tightness a mortar or concrete may require a slightly larger proportion of fine grains in the sand than for maximum density or strength. In general it may be stated that in monolithic construction a wet mixture, a rich concrete and an aggregate proportioned to secure great density will in the majority of cases give the desired results. It is impossible to specify definite thicknesses of concrete to prevent percolation under different heads of water, because of variations in proportions and methods of laying.

2. By special treatment of the surface of the concrete. Various methods have been employed, such as plastering the surface of concrete with rich portland cement mortar in proportions 1: 1 or 1: 1½. Water-tightness may also be secured by the use of a granolithic finish; by troweling the surface so as to produce a hard finish. Layers of water-proof paper or felt cemented with asphalt or bitumen or tar are extensively used, and sometimes asphalt alone. A mixture of alum and lye has also been used.

3. A water-proof concrete can be prepared by the application of fluates. The operation however, requires a great deal of time and labor. By the application of an 8 per cent solution of potash soap, instead of water, in mixing, the concrete can be rendered water-proof, so as to fulfill all requirements as to permeability of water.[2]

The first method suggested, is unquestionably the best to secure permanent water-tightness and the writer is not in favor of using water-proofing ingredients or of making surface applications except in cases where such may be required by reason of imperfections in the original concrete.

EXPANSION AND CONTRACTION

The coefficient of expansion of concrete is practically the same as for steel, about 0.0000065. Concrete is sensitive to temperature

[2] See Waterproof Concrete, by Albert Grittner, *Proceedings Sixth Congress International Association for Testing Materials.*

changes and expansion joints should be provided in all retaining walls not reinforced to take temperature stresses every 30 to 40 feet throughout the length of the structure. Prof. A. L. Johnson has attempted a mathematical demonstration of how to prevent contraction as follows:

Continuous walls will crack vertically in lengths such that the weight of the section multiplied by the coefficient of friction on the soil is equal to the tensile strength of the wall. The temperature required to crack the wall in these lengths is that temperature requiring a shrinkage in excess of the ability of the wall to stretch. Now, plain concrete can stretch very little before cracking. But concrete thoroughly reinforced with metal can take a proportionate elongation of 0.0018 before cracks will be developed. The maximum shrinkage that would be required, could not be due to a fall in temperature of more than 125°, The coefficient of expansion of concrete is 0.0000055, which for 125° becomes 0.0007 per unit of length, or less than one-half the ability of the reinforced concrete to stretch. No crack, therefore, could be produced with a fall in temperature of less than 250°, which of course, would be impossible to realize in practice. The quantity of metal used should be enough to equal the tensile strength of the concerte at the elastic limit of the metal. Calling the tensile strength of stone concrete 200 pounds per square inch, and the elastic limit of the steel 55,000 pounds (for high carbon steel) per square inch, the number of square inches of steel required would be $\frac{1}{275}$ of the number of square inches in the wall section.

Reinforced concrete retaining walls are commonly built without expansion joints. No amount of reinforcement can entirely prevent contraction cracks. The reinforcement will, however, distribute the cracks uniformly over the section; the greater the amount of reinforcement the smaller the cracks. The size and the distribution of the cracks will also depend upon the bond strength of the rods (Ketchum).

The American Railway Engineering Association has adopted the following:

Reinforcement for shrinkage or temperature stresses shall be not less than 0.33 per cent of a form of bar capable of developing a high bond resistance and shall be placed near the exposed surface of the concrete.

In calculating the steel required to reinforce for expansion and contraction, the temperature stresses in the steel must be considered.

If the steel drop in temperature 100° the temperature stress in the steel $= 100 \times 0.0000065 \times 30{,}000{,}000 = 19{,}500$ pounds per square inch. If the tensile strength of the concrete be 200 pounds per square inch and the elastic limit of the steel be 60,000 pounds per square inch, the available stress in the steel $= 60{,}000 - 19{,}500 = 40{,}500$

pounds per square inch and the required percentage of steel is $p = \frac{200}{40,500} = 0.0049$ or 0.49 per cent. While calculations show that the percentage of longitudinal steel reinforcement for expansion and contraction should be from 0.4 to 0.67 per cent, depending upon the elastic limit of the steel employed, yet experience has shown that walls reinforced with from 0.1 to 0.3 per cent of steel have given very satisfactory results, where the foundations are stable. Where there is any tendency for the wall to be thrown out of alignment the full amount of reinforcement should be used. The reinforcing steel for temperature stresses should be placed as near the exposed faces as practicable, and the rods should preferably be of small size.